# Symposium: Research Methods Involving Children's Drawings in Mathematical Contexts

In this symposium we present and discuss some methodological issues and possible solutions that have been encountered during our research into children's mathematical thinking, behaviours and affective responses, as reflected, at least in part, through their drawings. It has been claimed that, "Drawing can be a window into the mind of a child" (Wolek, 2001, p. 215). Such a statement implies that a child's self-created drawing can provide an indication of his/her internalised mathematical perceptions and conceptions. Note that the word 'drawing' can be used as either a noun or a verb, and hence can refer to either a completed artefact or to the dynamic act of creation. Depending on the aims, theoretical perspective and context of the study, researchers may focus on one form of 'drawing' or explore both forms.

Although drawing has long been an expected component of children's mathematical activity, rigorous research methods utilising mathematical drawings have remained somewhat underdeveloped. In recent years, a number of researchers have grappled with the design and development of specific aspects of methodology in their separate projects. With few established research methods for guidance, researchers have been creating and refining task designs, interview protocols, data capturing strategies, analysis techniques and interpretation processes for their studies of children's mathematical drawing. Each of the symposium papers presents a different research tool or technique that has been developed within its own unique context, with the purpose of stimulating discussion and advancing the development of effective research methods in the field of children's mathematical drawing.

Wolek, K. (2001). Listen to their pictures: An investigation of children's mathematical drawings. In Cuoco, A. (Ed.), *The roles of representations in school mathematics*, NCTM 2001 Yearbook, (pp. 215-227). Reston VA: NCTM.

**Chair/Discussant**: Joanne Mulligan

**Paper 1:** Amy MacDonald & Steven Murphy *Using the drawing-telling approach to reveal young children's mathematical knowledge.*

**Paper 2**: Jennifer Way & Jennifer Thom. *Capturing the mathematical drawing process using a digital pen.*

**Paper 3**: Kate Quane, Mohan Chinnappan & Sven Trenholm. *The nature of young children's attitudes towards Mathematics.*

**Paper 4**: Jill Cheeseman & Andrea McDonough. *Coding young learners' pictorial responses to an open-ended assessment task.*

2019. In G. Hine, S. Blackley, & A. Cooke (Eds.). Mathematics Education Research: Impacting Practice *(Proceedings of the 42nd annual conference of the Mathematics Education Research Group of Australasia)* pp. 99-116. Perth: MERGA.

# Coding Young Learners' Pictorial Responses to an Open-ended Assessment Task


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Following the teaching of a unit on mass measurement to 274 children (6 to 8 years of age), each of 13 classroom teachers administered an open-ended assessment task. Children represented their perceived knowledge of mass measurement in response to an "Impress Me" prompt. Drawn and written recordings were complex and multi-dimensional, ranging from drawings and/or descriptions of activities children had undertaken or materials they had used, to the articulation of understandings related to foundational ideas of measure. The complexity of categorising and coding the pictorial responses of children is central to this paper. Interpreting children's drawings is not straightforward and this has implications for classroom teachers.


Often, young children possess informal knowledge of mathematics that is "surprisingly broad, complex, and sophisticated" (Clements & Sarama, 2007, p. 462). Ideas of measurement begin to develop early (Lee, 2012) and while direct measurement is relatively simple, complex mental accomplishments are involved in measuring (Wilson & Osborne, 1992).

With calls for increased focus on the assessment of measurement understandings, and the recognition of complexity in measuring, methods of assessment that better, or differently, allow complexity in children's understandings to be revealed are warranted. Children's perspectives on their learning of measurement can provide insights and can inform teachers' interactions with young learners (McDonough, 2002). Drawings are a familiar form of expression for most children and, for some, may be preferred over writing. Drawing can also be a "powerful medium for discovering and expressing meaning; for the young child, drawing brings ideas to the surface" (Woleck, 2001, p. 215). Our overarching research question investigated children's thinking about measuring mass. To provide insights into their thoughts, young learners responded to an open-ended assessment task by drawing and/or writing. Here we look at the processes we used to reliably interpret, categorise, and code learners' responses.

## Method

Thirteen teachers from three schools taught a sequence of five lessons from our original teaching experiment (Cheeseman, McDonough & Ferguson, 2013) to 274 Year 1 and 2 students. The teachers then assessed the children's understandings by administering a task called "Impress Me", giving each child a sheet of A3 paper and reading the following prompt:

> We have been doing lots of weighing lately. I want you to show me on this piece of paper all you know about mass and weighing. You can write or draw or do both! Take your time and show your ideas and thinking as best you can. I want you to "impress me" with all you know about mass and weighing.

Children could choose to draw, write, or combine the two in conveying their understandings. This was seen as a flexible, responsive, sensitive approach to assessment that could benefit and liberate teachers and students (Woleck, 2001).

The data were analysed using a grounded theory approach. A central feature of this analytic approach is a general method of comparative analysis (Glaser & Strauss, 1967). In

this methodology, theory may be generated initially from the data, or, appropriate theories may be elaborated and modified as incoming data are meticulously played against them. Researchers can also carry into current studies any theory based on their previous research, providing it seems relevant and theory matching is rigorously carried out (Glaser & Strauss, 1967). Each of these approaches was used to analyse the data discussed here.

### *The process of coding*

Our focus here is describing the process of categorising and coding the data to summarise findings and describe patterns. All responses were read and each element - written, drawn, or both - was identified and clustered so that similar descriptions of students' responses were gathered. Patterns emerging from the data were sought. This initial reading of the data required modification as the classification was descriptive and lacked a measurement theoretical framework against which the data could be interpreted. In previous work in the Early Numeracy Research Project (ENRP), we developed and tested a research-based theoretical framework of "growth points" for mass measurement (Clarke et al., 2002). We adopted this framework to interpret the present data and each element of the responses was re-coded accordingly.

It is known that evidence may be coloured by prior knowledge when coding responses but it is enriched by the knowledge too as it provides some background to the thinking revealed by children. Questions about the reliability of our interpretation of the responses arose. To improve internal reliability, 25 percent of the children's work was re-coded to examine consistency between researchers and test whether similar conclusions could be reached independently about children's responses. Two teachers skilled at interpreting young children's written and pictorial ideas applied the defined categories and codes. The results produced an inter-rater reliability (traditionally measured as percent agreement, calculated as the number of agreement scores divided by the total number of scores) of 77 percent. All points of difference were discussed and an agreed understanding of the data was reached. New, tighter, definitions of the categories and codes were written. The inter-rater reliability test showed that: the categories that emerged from the data were applicable; some category descriptors required clarification; and the theoretical mass measurement framework was suitable although it required some elaboration.

### *The modified theoretical framework*

For each of the five ENRP growth points (GP), two sub-categories were defined: Emerging and Deeper. Often there was not enough information or clear enough information for a response to be classified as meeting that growth point (Deeper), as illustrated in the following descriptors for GP3 Emerging: "Names or draws informal units (e.g., plastic teddies) with no, or unclear context. Draws balance scales with possible informal units but unclear or no labelling/explanation". To be categorised as "Deeper" a drawing/writing needed to show an awareness of the concepts underpinning the growth point. For example, for GP3, the child's response needs to show awareness of the principles of non-standard units (e.g., same mass unit). With these ideas in mind, we defined a 10-point scale (Fig. 1). The entire data set was re-coded applying the new protocols without any reference to the previous coding. Figure 2 is an illustration of the analysis of the coded data.

## Results

In response to the Impress Me prompt each child produced an average of two and three drawings/writings (total n = 720). The distribution of all of the coded responses (Fig. 2) shows that very few drawn/written responses displayed no awareness of mass measurement

(n = 5). Almost one third of responses (31%) were categorised as growth point (GP) 1 and the large majority (193) of them displayed a deeper understanding of the attribute of mass. Examination of the results reveals that the 6 to 8 year-old children drew representations displaying their knowledge of mass measurement that was beyond the intended curriculum (approx. GP1 - GP2). Space restrictions prevent further analysis of the findings here. However, one observation is pertinent to the coding processes that are our focus – the definition of the sub-categories (emerging and deeper). Figure 2 shows that at GP2 and beyond, more children demonstrated emerging ideas of measurement concepts specified by the growth point than those who had developed a deeper understanding of those concepts. Due to the use of these codes we could see evidence of children's emergent learning across the mathematical framework.

| | |
|---|---|
| 0 No apparent awareness of mass | |
| 1 Awareness of the attribute of mass and use of descriptive language | |
| 1A Emerging | Includes some mass terminology as single words or a list but with no or unclear context (e.g., mass, weigh, weighing, scales, measuring, hefting)<br>Pictures and/or descriptions are unclear or incorrect |
| 1B Deeper | Includes some correct explanation for mass terminology (e.g., mass or weighing is finding heavier/lighter/equal)<br>Contexts are correct or appropriate (e.g., feather is light; brick is heavy; or reference to lessons where working with the attribute) |
| 2 Comparing, ordering, & matching with the attribute of mass | |
| 2A Emerging | Provides a description of the outcome of hefting or use of balances scales (e.g., finding heavier, lighter, the same, the answer, or as ordering)<br>Comparison is shown through drawings of hefting or balance scales but with no or some incorrect labeling |
| 2B Deeper | Describes/draws hefting or balance scales to compare mass of single objects with correct labelling (e.g., as heavier, lighter, heavy goes down) |
| 3 Quantifying mass accurately, using units and attending to measurement principles. | |
| 3A Emerging | Names or draws informal units (e.g., plastic teddies) but with no or unclear context<br>Draws balance scales with possible informal units but unclear or no labelling/explanation |
| 3B Deeper | Draws measuring using balance scale and informal units with correct labelling (e.g., one object measured with multiple same mass informal units)<br>Describes process of weighing with informal units showing understanding |
| 4 Choosing and using standard units for estimating and measuring mass, with accuracy | |
| 4A Emerging | Implies formal mass units (e.g., grams, kilograms) without context or labelling or unclear<br>Records terminology of grams and/or kilograms without context or incorrectly<br>Records equivalence (e.g., 1 kilogram = 1000 grams) |
| 4B Deeper | Draws or describes standard units of grams and/or kilograms (e.g., an object weighs x kilograms) |
| 5 Applying knowledge, skills and concepts of mass | |
| 5A Emerging | Refers to or draws weighing in an everyday, non-school context (e.g., people, food, post office parcels) or school context (e.g., playdough).<br>Use of different scales (e.g., digital, kitchen, bathroom, spring)<br>Shows some attention to relationships (e.g., size/mass; conservation of mass; gross/net) but complete understanding is not evident |
| 5B Deeper | Provides an interesting insight about a big idea of mass measurement<br>Clear articulation of relationships showing understandings (e.g., volume/mass; conservation of mass; gross/net) |

*Figure 1.* Mass Measurement Expanded Analytic Framework

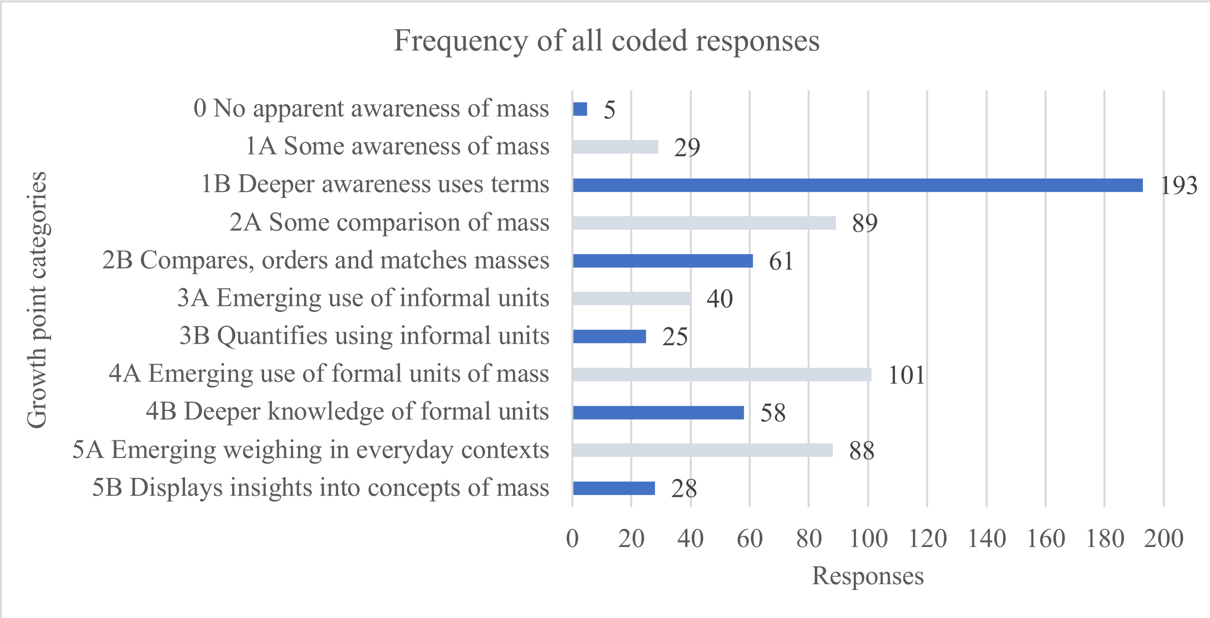


*Figure 2*. Distribution of all coded responses to Impress Me.

## Discussion and conclusion

The Impress Me protocol was effective in eliciting children's drawings that were complex and revealing. It was possible to "read" the recordings as mathematical diagrams, stories of actions, and lists of ideas. Individual students' thinking could be summarised in general terms by studying the drawings/writings and teachers benefited by hearing additional explanations. However, as an assessment tool and for our research, the data needed to be analysed to provide an overview of responses. Categories and codes were assigned to the recordings using an iterative process and a refined framework for synthesis and analysis. Results showed patterns in the data and the range of concepts children had communicated.

To build an overview of students' thinking we believe teachers would find a rubric that defined a hierarchy of responses to be useful. However, there are some issues to consider. Is the student's score based on the demonstration of the "highest" level of sophistication of thinking shown? Does each work sample element receive a score (as we did for the research)? The answers to such questions are not straightforward. What we are convinced about is the potential of children's drawn representations of their thinking.

## References

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